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SUBJECT: SUBMISSION FOR APPROVAL OF DRAFT AOP-32 (EDITION 1) – "DEMOLITION MATERIEL: ASSESSMENT AND TESTING OF SAFETY AND SUITABILITY FOR SERVICE"

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The U.S. Armed Forces approve the publication of AOP-32 with comment. Comments are attached at encl 1.

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Comments TO AOP-32 (EDITION 1)

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NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

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1. AOP -32 - (Edition 1) - DEMOLITION MATERIEL: ASSESSMENT AND TESTING OF SAFETY AND SUITABILITY FOR SERVICE is a NATO/PfP UNCLASSIFIED publication. The agreement of nations to use this publication is recorded in STANAG 2818.

2. AOP-32 (Edition 1) is effective upon receipt.

Jan H ERIKSEN
Rear Admiral, NONA
Director, NSA

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## INTRODUCTION

1. Purpose

This document gives guidelines for the assessment of the safety and the suitability for service of demolition materiel, the preparation and the conduct of the related testing and the evaluation of the test results.

2. Scope

2.1 This AOP is related to STANAG 2818, which covers two AOPs:

a. AOP-31: Demolition Materiel; Design Principles

b. AOP-32: Demolition Materiel, Assessment and Testing of Safety and Suitability for Service.

2.2 The description of demolition systems and short descriptions of principal demolition items (stores and accessories) are presented in AOP-31 [a2].

3. Reference Documents

Documents referred to in this publication are listed in Annex A.

4. Terminology

For the definition of "new demolition materiel", see STANAG 2818. In addition, the terms and definitions published in AAP-6 [a10] and AOP-38 [a11] are applicable.

5. Application

5.1 As required by STANAG 2818, methods and procedures for analyses, tests and assessments in this publication are established in accordance with the requirements for safety and suitability for service as laid down in AOP-31 and in the particular product specifications. These shall be applied for new demolition materiel submitted for qualification.

5.2 The formally designated National Authorities are to assess the munition and to determine whether the munition is a "new munition" (see STANAG 2818, Agreement).

5.3 The National Authority - responsible for qualification of the munition - shall determine whether the analyses, test plan and evaluation and the results thereof, meet the requirements of this AOP and the requirements for the tested munition. Therefore, control or supervision of the related activities by or on behalf of the National Authority is necessary.

5.4 Use may be made of analyses and test results obtained during the development of the munition (preferably controlled by the National Authority). Depending on verification of these data, these analyses may be accepted by the National Authority or if necessary following verification by means of small sample tests.

5.5 Where a component is to be used as a part of a different system then the outcome of tests and evaluation of results may have to be reassessed.

## TESTING AND EVALUATION

6. Materiel

6.1 Materiel to be Assessed

6.1.1 All new demolition systems and new elements for demolition systems shall be evaluated under the responsibility of the appropriate National Authority (see §5 above). The evaluation of a demolition system shall comprise the individual components, subsystems and the complete system in the configurations and environments as expected during their service life.

6.1.2 If new systems comprise existing qualified stores or accessories, a study shall determine whether their handling, environmental and interface conditions differ from previous use and whether the new elements are likely to affect system reliability or safety. Based on this study, the National Authority shall decide whether retesting of these elements is necessary.

6.1.3 If new elements are to be integrated into an existing qualified demolition system, these elements must be tested in combination with their interfaces. Complete system retesting will only be required if the use of the new elements could affect overall system reliability or safety.

6.2 Systems and Subsystems

6.2.1 Testing of complete (sub)systems is conducted to verify their operational characteristics, their (sub)system reliability and safety, the possibility of human error and the suitability of the user manuals. Full scale tests under normal and extreme operational conditions are highly desirable. During these tests, the operations shall be carried out in accordance with the user manuals and operational instructions.

6.2.2 In many cases, full size system testing will be limited to operational tests: handling and detection of human failure.

6.2.3 For the evaluation of most system characteristics, a breakdown of the system and separate testing of the individual elements and their interfaces will be more effective. See §6.3 below.

6.3 Individual Elements

6.3.1 Testing of individual elements of demolition systems is performed to verify:

a. correct functioning:

(1) the reliable transmission of the functions at the interfaces between donor elements (upstream in a train or a circuit) and acceptor elements (downstream);

(2) the internal functions (e.g. delay, boost); and

b. safety.

6.4 Conditions for Test Materiel

6.4.1 All test items shall be of a determined design (qualification lot), corresponding to a formally identified technical data package (which includes the product and component drawings and specifications and the user instructions[1]). They shall have been manufactured and inspected in accordance with a well defined and auditible production process and general quality control provisions. Further, they shall satisfy the quality requirements defined in the technical data package. Test results, obtained with items which differ from this design may be validated for the assessment, if the differences are fully identified and recognized as having no significant effect on the test results.

6.4.2 For the auxiliary items (not the test items themselves), to be used in the tests, in principle, accepted production build standard products shall be used, unless the choice of other or nonstandard auxiliary items is not liable to influence the test results.

## 7. Preliminary Activities

### 7.1 Preliminary Analyses

The test plan shall be based on thorough analyses conducted along the lines of AOP-31 [a2], AOP-15 [a6], AECTP-100 [a7], ARMP-1 [a5] or other NATO or national procedures. These analyses shall provide evidence that the requirements described in AOP-31, are met. This preliminary work should comprise the activities outlined below.

a. Comparison of the design (technical data package and user instructions) with staff requirements, including the mission and environmental profiles (cf. §8.2).

b. Verification of compliance with the requirements for performance, reliability, availability and maintainability. FMECA (Failure Mode, Effects and Criticality Analysis), FTA (Fault Tree Analysis) or other appropriate methods are to be used for this purpose. The effects of the environment and human failure on function of the demolition (sub)system, and its elements, must be taken into account.

c. Verification of compliance with the safety requirements; Hazard (Risk) Analysis, FTA or other appropriate methods will be used. The effects of the environment and human failure on the function of safety features shall be taken into account. The risk levels accociated with the demolition (sub)system, and its elements, shall be identified.

d. Verification of the conformity of the demolition system and all associated items with formal requirements (legislation, etc.). In particular it must be ensured that explosive stores, electrical components and fuzing systems have been qualified in accordance with the requirements outlined in Annex B hereafter and in AOP-31 [a2].

e. Study of environmental pollution, due to the effects of functioning and disposal of all stores, accessories and package material. This is to include assessment of any potential chemical pollution of soil, water and air.

f. Assessment of test results, obtained previously and during development.

g. Establishment of appropriate test methods and a test plan, based on the preliminary analyses to provide the necessary evidence that the requirements are met. Human failure analysis shall always be confirmed by the results of testing and assessment.

1 If user instructions are not available for the execution of the tests, the test procedures to be used shall be fully defined in the test plan. This test plan and the test results are to be taken into account when subsequently writing the user instructions.

7.2 Test Confidence

7.2.1 The level of confidence required shall be determined by the authorities responsible for the test plan. This level of confidence depends upon the associated risk levels, the importance of the materiel to be tested and economic considerations. The required confidence levels should be met by technical means and by the appropriate application of statistics.

7.2.2 Technically, the level of confidence depends upon:

a. the quality and control of the test configuration, environmental conditions;

b. the degree to which the test sample represents the population (munition) for which the conclusions will be validated;

c. the quality of the test equipment and instrumentation (calibration); and

d. the degree to which the test conditions represent the real life situations.

7.2.3 Statistically, the level of confidence depends upon:

a. the number times each test is conducted;

b. the number items testged; and

c. the efficiency of the test plan.

7.3 Test Plan

7.3.1 Testing shall be performed in accordance with a detailed test plan which is to include the following:

a. Identification of the munition (test items and ancillary items) by reference to its definition (data packages) and descriptions.

b. Reference to, or description of, test procedures/methods, test configurations and test levels. The disposition of the munition during the test shall be in accordance with the technical instructions and the user instructions.

c. The test sequences for each item under test.

d. The number of tests and test items necessary to obtain sufficient confidence.

e. The test conditions and the requirements for data collection (observations, measurement of the results).

f. Details of the measurement and observation equipment, measurement points and the required accuracy. The measurement and observation equipment shall be defined and identified prior to the test. Measurement points shall be defined in such a way that the safety and suitability characteristics of the test items will not be influenced.

g. Criteria for validation of the tests based on the reference documents (STANAGs, AOPs or other test procedures).

h. Methods of examination and/or disassembly of the test samples.

i. The criteria for acceptance of the results of each test, based on the Staff Requirement, on the analyses of safety and suitability for service and safety, and on the recommendations and requirements given in the reference documents (STANAGs, AOPs, etc.). The criteria for acceptance of test results shall be exactly defined.

j. Safety precautions for personnel and environment.

k. Procedures for the disposal of explosive and toxic waste and unexploded munitions.

l. Other data required by the test procedure.

8. Test Methods

8.1 Choice of Test Methods

8.1.1 Based on results of the preliminary analyses, test methods and test levels/severities shall be chosen to allow assessments of performance, reliability and safety of the materiel to the required level of confidence. Preference shall be given to test procedures, referred to or described hereafter and in Annex B and to NATO standardized test methods or procedures, quoted in Annex A. These procedures and methods indicate also to what extent these are mandatory or optional. Where no standard methods or procedures have been normalized within NATO, standard national procedures should be applied. Cost-effectiveness considerations will also be decisive.

Nevertheless, mandatory tests (e.g. tests for hazard classification) shall be executed in accordance with the referred documents (STANAGs or other) in their latest editions.

8.1.2 Human factor testing shall be included in order to assess the risks resulting from human failures caused by fatigue, adverse weather conditions and battlefield stress and related to poor design of controls and control panel and/or unclear or incorrect user instructions.

The results of the preliminary analyses may justify not conducting certain standard tests. If correct functioning or the absence of a negative (unwanted) response of the materiel can be proved theoretically to the required level of confidence, testing of the related environmental aspect can be waived.

Conversely, the analyses may demonstrate the necessity to carry out additional tests to satisfy specific needs, e.g., fail-safe tests.

8.2 Environmental Testing

8.2.1 General

8.2.1.1 The munition must be and must remain safe in all situations foreseen during its entire life cycle. The munition must be suitable for service and function reliably in its operational environment after the preceding part of its life cycle. Therefore, environmental testing is conducted to precondition the munition to determine the effects of the expected "normal" and "extreme" environmental stresses on safety and suitability for service.

8.2.1.2 The choice of the environmental conditions to which the test items have to be subjected should be based on:

a. the life cycle profile (including service life and disposal), and a characterization of the corresponding environmental factors acting therein;

b. the actual configurations in which they are likely to be used; and

c. the possible effects of these environmental factors on the safety and functional characteristics of the materiel.

8.2.1.3 Descriptions of the various operational and storage life conditions likely to be encountered are given in the Staff Requirement, user manuals and technical data packages (see also AOP-31 [a2]). Sometimes, specific environments are defined by the corresponding test specifications, as the IM tests [c..].

8.2.1.4 The environmental tests concern: simulation of climatic, mechanical and electrical/electromagnetic factors and human failure. These simulations shall represent:

a. the extreme conditions specified for the life cycles which are likely to affect the functional characteristics; and

b. more severe and accidental conditions which are likely to affect the safety characteristics.

8.2.1.5 Human factors and climatic factors such as temperature, moisture, water pressure and wet freezing, transport and handling in rough terrain, electromagnetic radiation and electrosatic discharge are all important for demolition materiel.

8.2.1.6 For safety assessment, better confidence is required than for suitability assessment. Therefore, for safety tests, the environmental stress levels to be applied will usually be more severe than for functional tests.

8.2.1.7 The environmental test methods will be chosen, in relation to their capacity to cause degradation of the test items safety and functional characteristics similar to that encountered in service life. Modelings may be used for this purpose if this has been validated. Distinction shall be made between reversible or irreversible responses of the materiel. Immediate risks shall be assessed as well as risks which can be expected in situations and events in the life cycle (handling, function, disposal, etc.).

8.2.1.8 During environmental testing of individual elements or subsystems, assemblies, subject test item may be assembled with upstream and downstream elements. These assemblies shall also undergo the environmental tests in order to verify the safety and suitability for service of the assembly at the interfaces.

8.2.2 Preconditioning

8.2.2.1 The purpose of preconditioning of test items is to subject them to the environmental stresses likely to occur prior to use (storage, transportation and, if applicable, maintenance) of the munition and which could degrade its S3 characteristics.

8.2.2.2 During preconditioning, the munition shall not become unsafe and the safety for future use shall not be compromised (reversible and irreversible failures). The availability of the test items shall not be compromised due to irreversible failures.

8.2.2.3 These effects can be established by assessment, direct observation (e.g. a premature explosion during any test, exudation during a heat test), measurement (heating or abnormal dynamic response during vibration) or X-ray during the preconditioning process. If it is impossible to obtain this information by non destructive methods, a number of test items may be taken out of the test sequence for functioning, breakdown and/or examination.

8.2.3 Conditioning During Functional and Safety Tests

8.2.3.1 Simulation of the environmental conditions during deployment and use of the munition will, in many cases, be obtained by reproduction of the real operational environments: unpacking, handling and deployment, and if possible under the foreseen climatic conditions.

8.2.3.2 For functional tests, the environmental conditions at the moment of functioning, thus at any time after deployment, when the demolition system is ready for firing must be considered.

8.3 Configuration

8.3.1 The configuration of the test items and the auxiliary support and test materiel shall be defined in accordance with the technical instructions and the user requirements. Some configurations to be considered are:

a. packaged or unpackaged;

b. all situations during deployment; and

c. assembled or not (to test the interfaces).

8.3.2 If the package has no significant screening effect (e.g., a wooden box during an EMR test or a metal container during a long duration temperature soak) the munition may be tested packaged or unpackaged.

8.3.3 Preference shall be given to the most unfavourable conditions and situations which may arise taking into account human influence, physical variations (dispersion of dimensions, positioning at the interfaces, etc.) and environmental influences: packaged and/or unpackaged, as applicable.

8.3.4 For reasons of safety, explosives may be removed and replaced by inert material provided this will not have any influence on the test results. The disassembly and reassembly, if needed therefore, shall not affect the resistance to environmental effects (e.g. water tightness during a rain test). Further, the material shall have identical characteristics in respect of the test parameters (e.g., conductivity during an EMR test).

8.4 Test Sequences

8.4.1 To reveal life cycle effects, sequential testing is the most appropriate, as this represents the cumulation of the irreversible or simultaneous effects.

8.4.2 If it is necessary to establish the causes of failures, special test plans (e.g. Taguchi-plans, cf. [d1]) may be useful in defining test sequences.

8.4.3 Items of the test sample may be submitted to one individual test in the following cases:

a. if the test severity is such that the influence of other environmental factors may be neglected; and

b. if it is evident that there is no significant interaction with other environmental factors.

9. Functional Tests

9.1 Test Objectives and Conditions

9.1.1 Functional tests are carried out after preconditioning to assess:

a. transmission of functions between the elements of a train or a circuit and

b. the internal functions of the elements, and

the total performance of the system.

9.1.2 Performance tests will usually comprise function of the store (demolition charge) on a target representative of that defined in the Staff Requirement. These tests may be improved by means of measurement of functional and safety parameters as indicated in AOP-31.

9.1.3 Internal function tests may be performed to assess specific internal functions such as boost or delay. The characteristics of the internal functions and their measurements depend on the input and output characteristics of the related elements and the relationship between them.

9.2 Function Transmission Tests

9.2.1 Within a functional train, each donor element is connected to one or more downstream elements in order to transmit the expected function through their interface.

9.2.2 The tests on transmission of function are to determine the probabilities of the reliable initiation of an irreversible function of the acceptor element when the latter is exposed to a stimulus originated by:

a. a human action to command fire to an initiator or a firing system (mechanical) or

b. an output stimulus from a donor element (pyrotechnic or electric).

9.2.3 Three types of tests can be distinguished:

a. transmission between two test items: to assess the reliable transmission of the required function from a donor element towards the required function of an acceptor element (“real life” simulation);

b. sensitivity level of an acceptor test item: to determine the minimum stimulus of a donor element (“witness”) which is capable of causing reliably the desired reaction of the test item; and

c. output level of a donor test item: to assess the capacity of the output stimulus to cause reliably the desired reaction of a "witness" acceptor element.

9.2.4 The "witness" element should be or represent an existing element which belongs to the system, which can be connected to the element to be tested:

a. upstream, for sensitivity tests or

b. downstream, for output tests.

9.2.5 The two elements are to be assembled in the configuration and the tolerances stated in the user instructions and the technical specifications. If the most unfavourable (or more severe) conditions only are to be assessed, the test is a "fixed level test"(§11.1). If however a test parameter is to be varied, the test is a "multiple level test" (§11.2).

9.2.6 If both elements are representative for their respective populations, the results shall be accepted as valid for the test configuration and environmental conditions and inferior severities thereof.

9.2.7 The transmission of the explosive reaction is satisfactory, if the output of the donor provides the correct initiation or ignition of the acceptor.

9.2.8 The sensitivity of most pyrotechnic and explosive devices is usually affected by repeated or prolonged application of the functional stimulus. Therefore, normally, each test item and each witness element shall be stimulated only once.

9.3 Indirect Methods

9.3.1 In the case where characterisation of an explosive train by means of a direct test (using witness charges or elements, cf. §9.2) cannot be used (for technical or cost reasons), indirect methods may be used by measuring the output level, or by simulation of the input stimulus provided the relation with the functioning of the real elements is demonstrated.

9.3.2 Indirect tests may be undertaken:

a. to test sensitivity: application of a standard stimulus, e.g. in a drop test apparatus or by a standard charge representing the donor elements;

b. to test the output power: measurement of the energy or the impulse, e.g. in a pendulum, or by observation of the reaction of a standard pyrotechnic element representing the acceptor elements.

9.3.3 For sensitivity tests the input stimulus shall be based on the same physical characteristics as those which control the initiation of the acceptor. Likewise, the measurement of the output shall comprise the characteristics which determine its donor function in the train. The relations with the real situations shall be known.

9.4 Sensitivity Measurements

9.4.1 To satisfy any sensitivity test, an element of a pyrotechnic or explosive train shall, upon receipt of the specified input stimulus,reliably produce the anticipated output effect.

9.4.2 The input stimulus may be:

a. the effect of a striker pin, friction, etc., produced by human action or transferred by a mechanism,

b. effect of an electrical pulse, produced by an exploder, a capacitor or a battery discharge (electrical igniter or element of an electrical circuit);

c. flame or shock (pyrotechnic or explosive element); or

d. other: e.g., a laser beam.

9.4.3 The input stimulus shall be controlled and be as representative as possible of the operational use conditions: type and magnitude of the output stimulus of the donor. The preferred stimulus is the one of a donor belonging to the system.

9.4.4 Examples of parameters characterizing the input stimulus are:

a. mechanical: drop height or mass and the drop weight;

b. electric: duration and/or intensity of the pulse, capacity of a condenser, frequency of a signal;

c. pyrotechnic, defined by the donor in the configuration of the assembled munition: flame temperature, composition of the reactive products, pressure or velocity of a shock wave, materials and shape of the envelopes, distance between donor and acceptor elements.

9.5 Output Measurements

The output effects may be measured or observed: either directly by a witness acceptor element, or indirectly: by measurement of parameters characterizing the output (e.g. detonation pressure and/or velocity, perforation of witness screens, gas volume, energy, composition: gasses, particles, etc.). For the use of a witness element, see §9.2.

9.6 Internal Functions Tests

9.6.1 The aim is to test the functioning of the smallest testable item under normal and extreme environmental conditions.

9.6.2 Typical failures are: no output, output level out of limits, delay out of tolerances, gas leakage in igniters, unacceptable damage of a mechanism.

10. Safety Tests

10.1 Test Objectives

10.1.1 Safety tests are conducted to assess:

a. the explosive safety of the demolition stores;

b. the environmental effects of the explosion, e.g. to establish danger areas and pollution effects of the explosion;

c. the reliable function of safety features;

d. assessment of safety failure modes and probabilities (eventually in combination with reliability/performance tests);

e. assessment of effects of human factors and the environments on safety, including special severe environments (MURAT/IM tests); and

f. detection of hidden failures (sneak testing).

10.1.2 To establish the boundary conditions for safety, values outside the normal limits can be chosen for critical parameters (distance between stores, climatic conditions, etc.). See also §11.1 below: margin tests.

10.2 Test Severities

10.2.1 For safety assessment, with regard to environmental simulations and configurations, and in particular with regard to major risks, extreme but credible worst case situations should be considered.

10.2.2 As far as possible, the explosive elements of demolition systems should undergo the tests on reduced vulnerability (IM) according to STANAG 4439 [a8].

10.2.3 The degree of safety is determined by observation of the reactions of the munition and/or examination of the items.

10.3 Sensitiveness/Susceptibility Tests

These tests are designed to determine probabilities of unwanted reactions of an acceptor charge or other element of the demolition system when it is submitted to an environmental or unexpected stimulus: electricity, friction, shock, etc. Like functional sensitivity tests (§9.4), these tests are arranged according to a statistical model as up-and-down tests or as margin tests, applying loads beyond the specified limits (§11.1).

11. Test Models

11.1 Fixed Level Tests

11.1.1 When testing demolition subsystems and individual elements, the functional stimulus (signal, electrical energy, explosive effect) shall be applied:

a. To verify reliability: at the most unfavourable output level of the donor element with regard to all-function (sensitivity) levels of the acceptors (usually the lowest output stimulus which will cause certain functioning of the test item); and

b. To verify safety: at the most unfavourable level induced by a specified environment into the system towards the subsystem or the element with regard to a no-function threshold of the acceptor (usually the highest stimulus which will not cause the test item to function).

11.1.2 Margin Tests consist of the application of loads at fixed levels beyond normal ranges for critical parameters. Margin tests may be useful to estimate margins for critical parameters or to achieve a better confidence if the number of tests is too small to obtain the desired statistical confidence.

11.1.3 Test level values (test severities) may concern:

a. the stimulus level (electrical, mechanical, duration);

b. the gap between donor and receptor;

c. confinement (expansion volume at the interface;

d. test temperatures;

e. tolerances with regard to the technical data package;

f. the stand-off distance of the a charge to the target, etc.

11.2 Multiple Levels Tests

11.2.1 Testing at extreme levels or beyond limit conditions may provide a pessimistic appreciation with regard to "normal" situations, which represent the major part of the life cycle.

11.2.2 A more realistic and precise estimation than by fixed level testing may be obtained by multiple level (up and down) testing, during which an essential functional parameter is to be tested at various levels. These parameters are basically the same as those applied for fixed level tests.

11.2.3 In many cases such as for sensitivity tests, the results are of the type "success/failure" (go/no-go, function or no-function of the item) at the tested levels are chosen to permit statistical evaluation. For the choice of an appropriate test model, see Annex C.

11.2.4 For go/no-go tests, exact criteria for "success" or "failure" must be specified.

12. Conduct of the Test

12.1 Principal Activities

12.1.1 The definition of the test items and associated stores, accessories and ancillary equipments and the disposition thereof during the test shall be closely controlled.

12.1.2 Testing shall be performed in accordance with the test plan and the test procedures defined therein.

12.1.3 Detailed measurement results and observations are to be collected and maintained to ensure their traceability. A list of hardware and software used during the tests is to be established.

12.1.4 Deviations with regard to the original test plan shall be reported. Corrective actions may then be necessary to re-establish conformance with the test plan.

12.2 Inspections, Measurements, Accuracy and Calibration

12.2.1 Visual, manual and instrumented inspections and measurements to verify physical characteristics (dimensions, etc.) shall be defined according to the data package.

12.2.2 The measurement and observation equipment shall be calibrated and maintained according to AQAP-130 [a9] (or AQAP-6) or to other equivalent international or national standards.

12.2.3 For test input and for response measurement the test accuracies specified in the test procedures shall be kept in. If these do not prescribe accuracies, the following accuracies are applicable:

a. for dimensions/distances: ± 2%

b. for duration: ± 1%

c. for environmental test parameters: see AECTP-300, AECTP-400 and AECTP-500 [b9].

12.2.4 However, if the preceding analyses lead to more restrictive tolerances, these shall be kept in.

12.2.5 Prior to the tests, all items shall be identified and verified by comparison with their data package and production identification (lot- or serial numbers).

12.3 Test Report

The test report shall refer to the test plan. It shall contain at least:

a. all deviations from the original test plan and from the documents referred therein;

b. meteorological conditions during open air tests;

c. all (summarized) test results with methods used for statistical elaboration;

d. the name of the authority responsible for the tests; and

e. dates and places of execution.

## 13. Evaluation of Test Results

### 13.1 Data Analysis

13.1.1 The test results shall be compared with the requirements for:

a. validation of the tests; and

b. qualification of the materiel tested.

13.1.2 Tests can be validated if they have been executed in accordance with the test plan or without unacceptable deviations and if no events happened which could affect the validity of the test plan.

13.1.3 Annex D describes statistical methods for assessment of the test results. These are particularly useful for the estimation of no-fire threshold and all-fire level from the results of sensitivity tests and output tests.

### 13.2 Conclusions

The tested materiel, in accordance with its production definition and as it has been tested in accordance with this AOP, can be qualified if:

a. the tests have been validated; and

b. either the test results meet the criteria imposed in the test plan, or are acceptable to the National Authority.

## REFERENCE DOCUMENTS

This Annex comprises major sources and background information for this AOP. Documents defining environments are presented in AOP-31 [a2].

a. General Reference Documents

[a1] STANAG 2818 (2): Demolition Materiel: Design, Testing and Assessment (Cover STANAG for the AOP).

[a2] AOP-31: Demolition Materiel, Design Principles.

[a3] STANAG 4123 and AASTP-3: Methods to Determine and Classify the Hazards of Ammunition; Manual for.

[a4] STANAG 4170, Principles and Methodology for the Qualification of Explosive Materials for Military Use.

[a5] STANAG 4174 and ARMP-1 and ARMP-2: NATO Requirements for Reliability and Maintainability/Application of.

[a6] STANAG 4297 and AOP-15: Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces.

[a7] STANAG 4370: Environmental Testing and AECTP-100: Guidelines on Management Planning.

[a8] STANAG 4439: Policy for Introduction, Assessment and Testing for Insensitive Munitions (MURAT) and AOP-39 (Guidance on).

[a9] AQAP-130: Allied Quality Assurance Publications/NATO Quality Assurance Requirements for Inspection and Test.

[a10] AAP-6: NATO Glossary of Terms and Definitions (English and French).

[a11] AOP-38: Glossary of Terms and Definitions Concerning the Safety and Suitability of Munitions, Explosives and Related Products.

b. Test and Assessment Procedures

[b1] STANAG 4145 and AEP-4: Nuclear Hardening Criteria for Armed Forces Material and Installations.

[b2] STANAG 4157 and Draft AOP-20: Fuzing Systems: Test Requirements for Assessment of Safety and Suitability for Service.

[b3] STANAG 4170 and AOP-7: Principles and Methodology for the Qualification of Explosive Materials for Military Use; Manual of Tests for.

[b4] STANAG 4239 and AOP-24: Electrostatic Discharge Test Procedures for Munitions to Determine the Safety and Suitability for Service of EEDs and Associated Electronic Systems in Munitions and Weapon Systems.

[b5] Draft STANAG 4242 and AOP-34: Tracked Vehicle Vibration, Munition Test Procedures.

[b6] STANAG 4324: Electromagnetic Radiation (Radio Frequency) Test Information to Determine the Safety and Suitability for Service of for Electro Explosive Devices and Associated Electronic Systems in Munitions and Weapon Systems.

[b7] Draft STANAG 4327(2) and AOP-25: Lightning Test Procedures for Munitions to Determine the Safety and Suitability for Service of EEDs and Associated Electronic Systems in Munitions and Weapon Systems.

[b8] STANAG 4363 and AOP-21: Fuzing Systems: Development Testing for the Assessment of Lead and Booster Components; Manual of Development Characterization and Safety Test Methods for Lead and Booster Explosive Components.

[b9] STANAG 4370: Environmental Testing and AECTP-300: Climatic Environmental Tests, AECTP-400: Mechanical Environmental Tests and AECTP-500: Electrical Environmental Tests.

[b10] STANAG 4375: Safety Drop, Munition Test Procedures.

[b11] STANAG 4404, Safety Design Requirements and Guidelines for Munition Related Safety Critical Computing Systems.

[b12] Draft STANAG 4416 and Draft AOP-28 : Nuclear Electromagnetic Pulse: Munition Test Procedures.

[b13] Draft STANAG 4487: Explosives: Friction Sensitivity Tests.

[b14] Draft STANAG 4556: Explosives: Vacuum Stability Test .

[b15] Draft STANAG 4560: EED: Assessment and Test Methods for Characterization.

c. Documents Concerning IM (MURAT) Testing

[c1] STANAG 4240: Liquid Fuel Fire Test for Munitions; Draft STANAG 4240(2) comprising also the Mini Fuel Fire Test.

[c2] STANAG 4241: Bullet Attack Test for Munitions.

[c3] STANAG 4382: Slow Heating Test for Munitions.

[c4] STANAG 4396: Sympathetic Reaction.

[c5] Draft STANAG 4496: Fragment Attack Test for Munitions.

[c6] Draft STANAG 4526: Shaped Charge Jet Impact Test for Munitions.

[-] STANAG 4375: Safety Drop Test for Munitions: See [b10].

d. National Test Methods for Demolition Materiel

The following test procedures are used on a national basis.

France

[d01] DAT S1375F0082: Épreuve de puissance de détonateur et de cordeau détonant (Detonator and detonating cord power test)

[d02] Méthode Cherchar - Épreuve de puissance de détonateur (Detonator and detonating cord power test)

Germany

[d11] Sprengstoffgesetz; Prüfvorschriften für Sprengstoffe, Zündmittel, Sprengzubehör sowie pyrotechnische Gegenstände und deren Sätze (Legislation on explosives: Test directives for explosives, initiators, pyrotechnic devices and their explosive compositions.)

Netherlands

[d21] "Reaction zone measurements in high explosive detonation waves by means of shock induced polarization" by Dr. R.R. Ysselstein. Combustion & Flame, 1986, p.27-37.

[d22] PML-1988-67: Thermal Transient test (Report)

Sweden

[d31] SW: Swedish Standard

United Kingdom

[d41] Hopkinson Bar Method (RARDE)

United States

[d51] MIL-STD 331 Test 302: Detonator Output Measurement by Lead Disk

e. Background Information

[e1] Vigier: Pratique des plans d'expériences; Méthodologie Taguchi; 1988 (Practice of experiment plans; method Taguchi)

# TEST METHODS

## 1. Introduction

This Annex outlines test methods applicable to the assessment of safety and suitability for service of demolition (sub)systems, stores and accessories. It is intended to complement the guidance given in AOP-32. Advice in this Annex is advisory unless a specific test is identified in the staff requirement as mandatory.

The test methods outlined in this Annex do not constitute a comprehensive list of safety and suitability for service tests. Rather the complete test programme will be formulated following full analyses as described in §7 of this AOP. The results of the functional and performance tests should also be analyzed and applied for safety assessment.

The appendices provide descriptions of specific test methods.

## 2. Preliminary Testing and Assessments

### 2.1 Explosives

Explosives used in the manufacture of demolition stores shall be tested in accordance with AOP-7, and qualified in accordance with STANAG 4170 [b3]. However, life cycle analyses may reveal the need to perform supplementary tests for (type)qualification for use in particular demolition system(s). For example, mechanical tests such as those described in STANAG 4487 [b13], [b14], etc.

Materials used in the manufacture of the explosive charges shall comply with the requirements of existing NATO specifications, as applicable (STANAG 4022 for hexogene, STANAG 4025 for TNT, etc.).

### 2.2 Explosive Components

Explosive components which are (to be) used in demolition stores shall be submitted to safety testing. The test procedures given in STANAG 4363 and AOP-21 [b8] should be used where they are applicable to demolition materiel.

### 2.3 Electrical Components

All electrical components shall be tested and shall comply with the existing NATO requirements in force for the type of components (cables, plugs, connectors, etc.).

### 2.4 Fuzing Systems

If fuzing systems are a part of a demolition system, these shall be tested and shall comply with the requirements of STANAG 4157 and AOP-20 [b2].

3. Environmental Simulations

For the establishment of the environmental conditions, see §8.2 of this AOP.

Test methods which are generally applicable are defined in [b9]:

- AECTP-300 for climatic tests,
- AECTP-400 for mechanical tests and
- AECTP-500 for electric and electromagnetic tests.

STANAG 4242 with AOP-34 for vibration testing of munitions, [b5] shall apply if the demolition materiel is likely to be transported in tracked vehicles.

Special environmental safety tests are outlined in §7 below.

4. Demolition Charges, Terminal Effects

Tests to determine the terminal effects of demolition charges are performed to measure the effects on a target representative of that outlined in the staff requirements. These measurements may include:

- diameter and depth of perforation of the target, or rate of perforations of the target, by hollow charges,
- width and depth of cutting of the target or success rate of cutting of the target such as a rail or a girder, obtained by cutting charges,
- the behind armour effects at the target (by fragments or debris),
- clearance area of mines, by line charges,
- crater diameter and depth, by cratering charges.

The test arrangement depends on the type of charge to be tested. See also §9 of this AOP.

The evaluation of the output of charges can be improved by measurement of the following parameters:

- detonation velocity of the explosive charge, using any common technique (IR sensors, high speed camera, etc.),
- detonation pressure on the "output side" of explosive charges, by measurement of shock wave passage time through a polarized disk, or
- blast wave at given distances from the charge.

All explosive material shall have detonated completely after the explosion. Observation of the detonation by colour TV and search of the area for residual explosives are recommended methods of testing for this.
These tests are very important for safety aspects: establishment of danger areas, safety distances, and environmental effects (ground pollution, noise, etc.).

5. Explosive Train Elements

5.1 Transmission Tests

Direct transmission testing consists of assembling a donor element upstream, with an acceptor element downstream and to verify the functioning of this assembly (see §9.2 of this AOP). Some examples the arrangement of detonation transmission tests are given in Appendix 3 to this Annex . The tests may be performed at fixed level at normal or extreme conditions, or at multiple levels and at normal or extreme conditions (see the AOP §11). For the assessment of the reliability of the transmission, see Annex C.

5.2 Measurement of Sensitivity and Sensitiveness

As far as they are applicable to pyrotechnic/explosive demolition systems, sensitivity tests should be performed in accordance with STANAG 4363 and AOP-21 [b8]. Variable level and/or margin tests should be applied. See also §6 below and the AOP §9.4 and §10.3.

5.3 Output Power Measurements

Examples of the procedures for conducting output testing of explosive stores are outlined in Appendix 1 to this Annex. See also §9.5 of this AOP.

5.4 Input Measurements

An example of an indirect method for an input (sensitivity) test is the Explosive Component Water Gap Test (ECWGT), described in AOP-21 [b8].

6. Ignition and Initiation Elements

6.1 Mechanical Igniters and Initiators

6.1.1 Multiple Level Tests (See §11.2 of this AOP)

Step 1: Assessment of the mechanical energy or power of the functioning mechanism (e.g., striker pin) acting on the primer element. Both the mean and standard deviation should be calculated. If this is not feasible, an alternative is to establish a direct scale for step 2, e.g., by measurement of the indent into a crusher as a function of drop height.

Step 2: Estimate the sensitivity of primer element by means of variation of energy (power) applied onto the primer. A drop test consisting of dropping a weight onto a striker pin representing the striker pin of the mechanism is used. The drop height is adjusted to obtain go/no-go results.

Step 3: The expected maximum failure rate of the primer due to insufficient striker energy should be estimated from the distributions resulting from Steps 1 and 2 with the required confidence. See Annex C §4: Two Gaussian distributions, wherein:

$x_1$ = striker pin energy and

$x_2$ = limit function energy (sensitivity)

6.1.2 Margin Test (see §11.1 of this AOP)

Perform tests defined in §6.1.1 above with an adapted igniter/initiator mechanism to obtain a well defined reduction of the stimulus. This can be obtained by using a weakened spring or by reducing the length of the striker pin, etc.

Perform tests with complete igniter/initiator mechanism with the reduced stimulus from the mechanism. Estimate total failure rate using binomial or Poisson distribution.

6.2 Electrical Igniters and Initiators

6.2.1 Multiple Level Test

Step 1: Establish the minimum input pulse received by the EED from the firing control or the firing stimulus relay system. This can be obtained by measurement, or from the specifications of the demolition system (exploder, circuit characteristics).

Step 2: Establish the distribution of the sensitivity of the EED by variation of the main stimulus parameter (see §11.2 of this AOP):

- if the firing stimulus is a dc current, by variation of the current level or the pulse duration;
- if the firning stimulus is a dc capacitor discharge over a circuit with a specified resistance or impedance, by variation of the charge voltage and/or capacity.

The firing stimulus shall be produced by means of a pulse generator in order to obtain a well controlled pulse.

For bridgewire EEDs, dc sensitivity testing is usually sufficient.

Step 3: If the minimum input (Step 1) is higher than the all-fire level (Step 2) and no problems are encountered, the requirements will be met. If not, estimate the maximum failure rate of the EED at the minimum input (step 1) using the outcome of Step 2. See Annex C §4. The minimum input may have a fixed value, e.g., the specified minimum firing stimulus of the exploder (Annex C §3).

6.2.2 Series Tests for Electric Detonators

Test A (simulation of the real situation): Connect the detonators in series to the circuit using the maximum number allowed in accordance with the specification and the user instructions. The circuit shall be at its maximum allowable resistance. Subject the circuit to a firing pulse representing the minimum output. All detonators shall fire within the required time. The test shall be repeated until sufficient confidence has been achieved.

Test B (measurement of response times of EBW detonators): Determine the following response durations:

- $t_1$: the time duration between start of the initiation pulse and the irreversible reaction of the ignition composition, and
- $t_2$: the time duration between start of the initiation pulse and detonation.

The number of tests shall be sufficient to demonstrate with sufficient confidence that $t_2$-$t_1$>0.

Note: $t_1$ may be determined by measurement of (the effects) the sudden supplementary temperature rise due to the combustion of the ignition composition, in addition to the heat generation in the bridge wire (ref. [b15] and [d22], or by multiple level tests.

6.2.3 Margin Tests

Apply an input lower than the minimum input defined in Step 1 of §6.2.1 above. This artificial degradation can be obtained:

- for dc current pulse firing:
  * by decreasing the voltage or duration level,
  * by increasing the circuit resistance;

- for ESD firing systems:
  * by decreasing the capacity or the charging voltage of the condenser,
  * by decreasing or increasing the circuit resistance;

- for series tests (§6.2.2):
  * by increasing the number of detonators connected in series,
  * by increasing the circuit resistance.

6.3 Other Ignition/Initiation Devices

The approach is similar to the EED testing. The stimulus to be varied may be a laser pulse intensity or duration.

7. Explosive Stores; Special Safety Tests

All demolition supply stores shall be submitted to hazard classification or have been classified in accordance with STANAG 4123 [a3], having satisfied the tests prescribed in its AASTP-3. This is also applicable for explosive components which must be transported or stored separately, e.g. for refubishment of demolition stores.

Demolition stores should be submitted to IM (MURAT) testing in accordance with STANAG 4439 and AOP-39 [a8] and the related STANAGs [c1] through [c6]. Other environmental tests resulting from threat hazard assessment should, e.g., the drop test following STANAG 4375, and in particular for large explosive charges the high temperature test including radiative heating following AECTP-300 Method 302. See also §3 above and AOP-31 Annex C, section 6.

Examples of tests which have not yet been standardized by NATO are:

- kinetic energy projectile or self forging fragment impact;
- fall of an object on the munition;
- nearby detonations (effects on structural integrity).

and tests to determine the effects of electrical/electromagnetic environments on explosive fillings: ESD, direct lightning strikes, NEMP and EMR (see also §8 hereafter). As long as no agreed NATO procedures are available, national test procedures are applicable.

8. Demolition Accessories (non explosive)

Functional and safety tests of demolition accessories are directly based on the technical and formal requirements and the preliminary analyses.

Further, functional and safety tests for electrical and laser equipment are to be carried out in accordance with the specifications for the concerned materiel.

The objectives of this testing, combined with environmental testing, is to verify:

- reaction on specified input;
- transfer functions, if applicable;
- measurement of the output; and
- risks of producing an unforeseen output which could trigger the firing system or injure users during deployment and firing.

Particular safety tests concerning the risks related to the effects of environmental electrical/electromagnetic energy on munitions and munition systems are:

- EMR pick-up tests; see STANAG 4324 [b6].
- ESD tests; see STANAG 4239 and AOP-24 [b4].
- Lightning; see STANAG 4327 and AOP-25 [b7].
- (Nuclear) EMP; see draft STANAG 4416 and AOP-28 [b12] and STANAG 4145 and AEP-4 [b1].

These particular tests concern all situations but are particularly important during and after deployment, where the risks of external threats are the greatest.

# MEASUREMENT OF OUTPUT POWER

This Appendix gives examples of procedures for carrying out output tests. In most cases, the output is assessed by means of a standardized witness charge representing the most unfavourable expected situation. For "real life" situations, see Appendix 3 which follows.

Some of these test procedures are initially designed for assessment of interchangeability.

## 1. Demolition Charges

### 1.1 TNO method: Polarized Disk NL [d21]

The test specimen is fitted with its bottom (shock wave direction) directly on a plexiglass disk which is prepared for electronic measurement. On detonation, the time it takes the shock wave to pass through the polarized disk is measured in order to determine the detonation pressure at the bottom of the charge.

## 2 Detonators

### 2.1 Hopkinson Bar Method UK [d41]

The method consists of initiating 2 standardized pellets placed against the base by the test detonator. The output energy of the pellets is measured by means of a test pendulum.

### 2.2 Power Test FR [d01]

The test detonator is fitted in a holder, stuck on an aluminium disk with specified characteristics. The base of the detonator is directly in contact with the target. After detonation, the initiating power at the base of the detonator is determined by measurement of the diameter and observation of the perforation of the disk. The method replaces the former Médard Method.

### 2.3 Cherchar Method FR [d02]

This method consists of initiating a standardized pellet by means of the test detonator which is inserted into the pellet. The output energy of the pellet is estimated by means of a pendulum.

### 2.4 Lead Disk Test US [d51]

The test detonator is placed with its base directly on a specified lead disk. After detonation, the base output power is estimated by measurement of the diameter of the perforation of the disk.

### 2.5 TNO Method NL [d21]

The method is identical to the one for demolition charges; see §1.1. This test can only be used for detonators with a flat base.

2.6 Wöhler Method GE [d11]

The Wöhler test for detonators consists of measurement of the effect on a copper crusher from a standard phlegmatized pellet, initiated by the test detonator.

3. Detonating Cord

Note: The level of the output power of a detonating cord may vary over its length, due to ireegular explosive filling. Therefore, the output power should be verified at various points along the length of the cord to establish the dispersion of the output level.

3.1 Power Test FR [d01]

The method is identical to the one for detonators; §2.2. The output power is measured at the cutting face.

3.2 Measurement of Detonation Velocity

A length of at least 1.30 m of detonating cord is initiated by means of an appropriate detonator. The time interval of the detonation is measured electronically over a selected length of the detonating cord (e.g. 1 m) from a point 20 cm downstream from the detonator. Irregular filling of the cord may be detected by increasing the number of measurement points and shortening the distances between the measurement points, depending on the sampling frequency of the measurement system and the accuracy of the length of the measurement trajectories.

3.3 Witness Plate

The length of detonating cord to be tested is placed on, and in contact with a witness plate, without attachment to the plate. The indenting of the plate indicates if full detonation occurred and if the detonation was regular over the test trajectory. The significance of the indent depends on the output of the cord, the plate material, its thickness and the supporting material (e.g. sand). The plate material may be metal (Pb or Al) or any other suitable material. The results are compared with those of a qualified detonating cord.

## FUNCTIONAL AND SAFETY - ENVIRONMENTAL TESTS

This Appendix outlines some examples of functional and safety tests in specified environments, and outlines procedures for these tests.

1. Detonating Cord

1.1 Flexibility Test

The detonating cord is wound in 10 close turns around a 7 mm diameter bar, the cord being at the lowest operational temperature. After the test the detonating cord shall:

a. Not show any cracks in the covering tube.

b. Not show any gaps in the explosive core.

c. Remain watertight.

d. Be capable of full detonation in accordance with the specifications.

Means of observation are:

(1) simple optic means, e.g. magnifying glass;

(2) X-ray;

(3) witness plate or measurement of detonation velocity

See also the note at §1.3 below.

1.2 Tensile Test

The detonating cord is subjected to a specified tensile load, for a selected period of time at a specified temperature of the anticipated life cycle and the operational requirements and the user instructions. The test parameters may be adapted to take into account the user instructions.

After this test, the detonating cord shall:

a. Not show any cracks in the covering tube.

b. Remain secure at the points of attachment (clips, etc).

c. Not show any gaps in the explosive core.

d. Remain watertight.

e. Be capable to produce a full detonation in accordance with the specifications.

Means of observation and measurement are:

1. simple optic means, e.g., magnifying glass;
2. a tensile test arrangement with attachment of the specimen as foreseen in the demolotion system,
3. X-ray;
4. witness plate or measurement of detonation velocity.

See also the note at §1.3 below.

1.3 Humidity and Submersion Tests

These tests are intended to simulate humid air conditions and submersion. They are described in AECTP-300 Methods 306, 307 and 310 [b9]. For test severities, see AOP-31 Annex B[a2].

After the humidity and submersion tests, the detonating cord shall be capable of full detonation in accordance with the specifications.

NOTE: During climatic tests, moisture may penetrate into the open explosive core at the ends of the detonating cord. Therefore, these ends will need to be sealed for the test.

2. Safety Fuze

2.1 Humidity and Immersion Tests

For execution of the tests, see §1.3 above (detonating cord). A minimum requirement for the immersion test is to immerge the safety fuze for 24 hours under 30 cm of water at ambient temperature (20 ± 5 °C).

Following these test, the safety fuze shall have maintained its specified burning rate.

# DETONATION/COMBUSTION TRANSMISSION TESTS

This Appendix defines test procedures to assess the reliability of detonation transfer within an explosive train.

Several donor -> acceptor combinations are presented below. They represent the most common configurations likely to be used in a deployed demolition system. If the user manuals prescribe other configurations, these shall be added to, or replace the corresponding configurations shown below.

For observation or measurement of the result (correct function of the acceptor charge), see §9.2 of this AOP and Appendix 1.

## 1. Detonator -> Detonating Cord

This test represents the configuration: detonator and detonating cord taped together.

Place the detonator (electric or pyrotechnic) parallel to the detonating cord at a distance d (see fig. 1 below). This distance d is to be adjusted in accordance with the statistical model (Annex C) and it should represent the extreme distance over which detonation transfer could be expected (no-fire and all-fire levels).

The detonating cord shall extend sufficiently far in front of and beyond the detonator:

- upstream, to prevent pick-up of the detonation by an open end of the cord and
- downstream to allow reliable assessment of the output in accordance with Appendix 1.

Neither item should be fixed to a hard surface in order to avoid effects of reflection of the shock wave. No objects should be between the detonator and the detonating cord; means of fixation may be used before or beyond the detonation transmission zone (the length of the detonator).

Fire the detonator and register the response of the detonating cord over the measurement length **m** in accordance with Appendix 1.

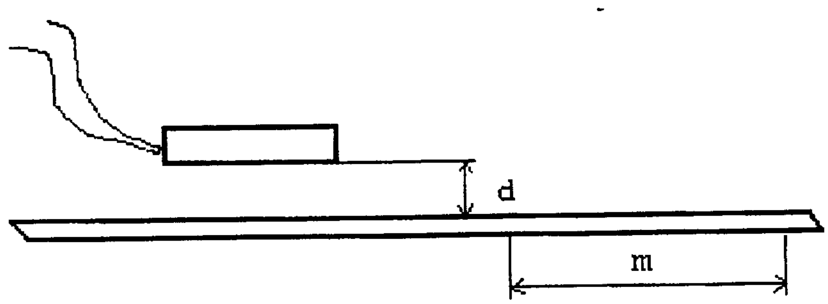



Fig. 1.1

## 2. Detonating Cord -> Detonating Cord

### 2.1 Parallel Position

The principle of this test is the same as for detonator -> detonating cord.

The donor detonating cord is placed parallel to the acceptor cord at a distance d (variable) over a length x ± 5% (e.g., x = 30 mm).

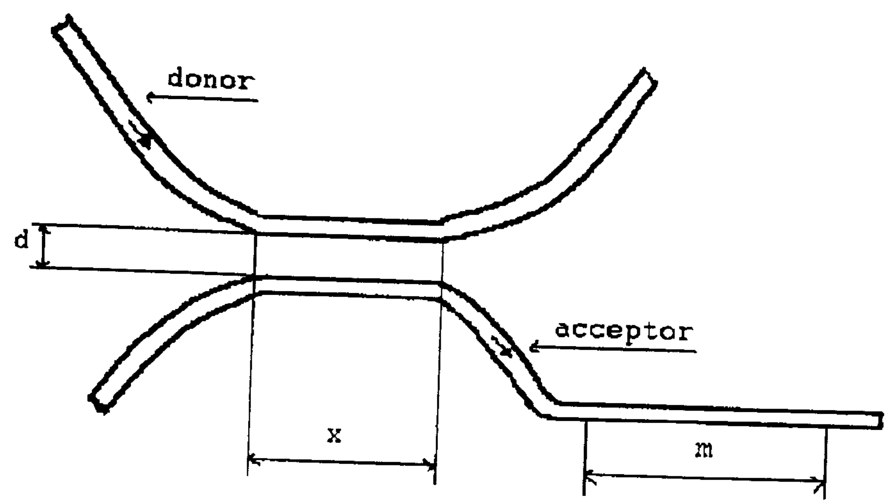
The incoming donor end shall be sufficiently long to ensure full detonation over the transfer zone x (e.g. 20 cm for standard 5 mm cord). The choice of the lengths should depend on the type of detonating cord and the required measurement length in accordance with Appendix 1.

The incoming and outgoing donor and acceptor ends should be directed away from each other to prevent any influence on the detonation transmission.

The test should be done twice:

a. the direction of the shock waves of the donor and of the acceptor running in the same direction; and

b. the direction of the shock waves of the donor and of the acceptor running in the opposite direction.




The witness cord should represent the type(s) of detonating cord which are intended to be used in combination with the detonating cord to be tested.

The test specimen shall have successively the role of donor and acceptor, with the "witness" cord in the role of acceptor resp. donor.

It may be useful not only to register the correct function of the acceptor but also the correct function of the donor detonating cord in order to support validation of the test.

2.2 Crossed Position

This configuration represents the use of a knot or a cross fixing to a second detonation cord e.g., by means of a clip. The acceptor line is laid under the donor line at an angle of approximately 90°. Both lines shall be in contact but not pressed together. A means of constraining the detonation cords may be used, but not, for the purpose of the test, at the point where the cords cross, in order not to influence transmission of the shock wave at the crossing.
Note: As no fixation at the crossing is foreseen, the test severity is high.

3. Detonator to Demolition Charge

3.1 Detonator to Demolition Charges having a Detonator Hole [2]

Place the detonator in the appropriate hole of the demolition charge as far as required and fix it in place in accordance with the user instructions. Fire the detonator in accordance with the user instructions.

Possibilities to vary test parameters are:

- reduced and increased power of the detonators (quantity of explosive or composition);
- diameter and depth of the detonator hole;
- depth to which the detonator is inserted.

3.2 Detonator to Plastic Explosive

Take a quantity of plastic explosive considered sufficient for a succesful detonation. Insert the detonator into the centre of the explosive, as indicated in the user instructions. Variables: The power of the detonator, or a smaller quantity of explosive for margin test, provided the diameter of the ball is greater than the critical diameter of the explosive.

4. Detonating Cord to Demolition Charge

This type of test is appropriate for testing detonation transmission from detonating cord to a demolition charge without a well, and to plastic explosives.

It is not intended to be used to test the detonation transmission to charges which, according to the user instructions, must be initiated by a detonator, a booster or a fuze or fuzing system.

2 Alternative terms: cavity, well.

4.1 Detonating Cord to Solid Explosive Charge

Wind the detonating cord around the demolition charge, ensuring close contact with the charge, over the smallest periphery, with at least one complete turn. Variable: the number of turns or the length of contact between detonating cord and charge surface. The length or number of turns which results in full detonation of the acceptor charge shall be noted. Fig. 3.1 shows a configuration with 3 complete turns of the detonating cord.

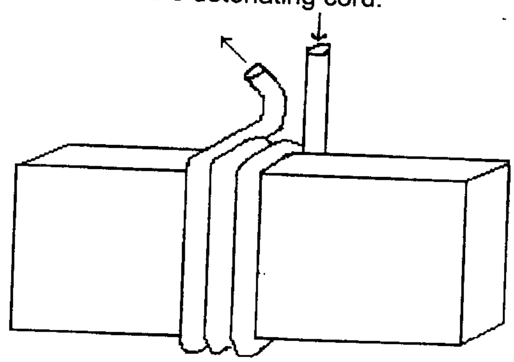


Fig. 3.1

4.2 Detonating Cord to Plastic Explosive Charge

Knead the quantity of plastic explosive around the detonating cord, as indicated in the user instructions. Variables (specially for margin tests):

- smaller quantity of plastic explosive (provided the diameter of the ball is greater than the critical diameter of the explosive);
- length of detonating cord to be inserted or margin test, e.g., or
- incomplete knot of the detonating cord.

5. Safety Fuze to Safety Fuze

The tests defined below are intended to measure the distance of transmission of the combustion of a safety fuze and the sensitivity of the receptor pieces in relation to the output power of donor pieces of safety fuze.

Two pieces of safety fuze with clean cut ends are placed opposite each other at the prescribed distance (normally 25 mm) in grooves in a steel plate (or other equivalent means) and held in place by an appropriate means (adhesive tape).One of the pieces (the donor) is ignited; the opposite end of this piece shall ignite the opposite acceptor piece.

Means of observation are:

- measurement of burning time over the 2nd length; and
- observation of the correct ignition of the witness charge.

This test procedure can be used as a margin test or as a variable level test by adjustment of the distance between the two ends.

6. Other Combinations

Some other configurations which might require testing are:

- detonating cord -> non-electric detonator,
- safety fuze -> non-electric detonator,
- detonator -> boost/lead charges,
- firing device -> safety fuze.

The tests should be arranged following the instructions in the user manuals. The tests are basically go - no-go tests. Test confidence may be improved by increasing test severity parameters such as temperature or distance between the donor and the acceptor elements.

# STATISTICAL ELEMENTS

1. General

The assessment of pyrotechnic events can in most cases only be achieved by means of one-shot tests: every test item can be tested only once and the outcome is "success" or "failure" ("go - "no go").

The results from tests repeated under identical conditions can be evaluated by means of the binomial or the Poisson distribution.

Main objectives of these tests are to estimate the no-fire threshold (safety) and the all-fire level (reliability).

For the assessment of these levels of the transfer of a function between two elements, the sensitivity/susceptibility range of the acceptor (all-fire or all-function levels) must be covered by the range of the output level (functional stimulus level) of the donor element with sufficient confidence. Its reliability must be compatible with the required complete system availability and reliability.

2. Reliability Estimation (See this AOP, §11 and §13.)

To estimate the functional reliability of individual demolition items and demolition systems, current statistical methods are applied.

Data can be obtained from the following sources:

- reliability data from existing data bases and literature concerning in-service stores or comparable items;
- analysis comprising statistical elaboration, for construction of the previsional reliability;
- tests and feed-back from users experience (exploitation of results and anomalies), for observed reliability.

Reliability R = 1 - failure rate Q. The failure rate Q of an individual demolition item is:

$Q = Q_1 + Q_2 + Q_3$ wherein:

$Q_1$ = failure of good pick-up (initiation, ignition) of the regular input stimulus from the next upstream element;

$Q_2$ = failure of good transfer function (signal treatment, delay, etc.) upon good pick-up; and

$Q_3$ = failure to give the required output upon good transfer

The failure rate of a chain is not only a function of the internal failures, but depends also on interface failures between upstream and downstream elements. This is important for demolition materiel, as there are many hand-made connections in a deployed system. If we define

$Q_{i-}$ = interface failure rate between the i-1 and i element of a chain, then the internal failure rate $Q_i$ of the i element in the chain or an explosive train of N elements (I = 1, 2, ..., N) is:

$$Q_i = Q_{i-} + Q_{i1} + Q_{i2} + Q_{i3} \qquad (1)$$

The overall reliability R = 1 - Q of the chain is:

$$R = 1 - \Sigma Q_i + \Sigma\Sigma Q_i Q_j,\ i,j = 1, 2, ..., N;\ i =/= j \qquad (2)$$

If within a deployed demolition system the initial stimulus is split in order to fire simultaneously several charges, formula (2) is valid for each line from exploder to charge.

If several charges are connected to one line, the reliability of the closest charges will be better then the reliability of the last one, whilst $\Sigma Q_i > \Sigma\Sigma Q_i Q_j$ for all i, j.

3. Failure Rate; Gaussian Distribution

This paragraph is applicable when a variable X must be compared with a fixed value $X_c$.

The failure probability follows from:

If
- $X_c$ = minimum input received
- X = mean sensitivity (50%) level of EED with standard deviation $S_x$ out of n observations,

then the maximum standard deviation $\sigma_{max}$

$$\sigma_{max} = \sqrt{\{(n-1) * S_x : chi^2_{n-1,\alpha}\}}$$

and the requirement $X_c > X$ will be fulfilled with confidence level (1-α)

if $X_c - X > t_{1-\alpha,\, n-1} * \sigma_{max}$

The estimated failure rate is the probability that $X_c - X > 0$

4. Failure Rate; Two Gaussian Distributions

This paragraph is applicable when two variables, $x_1$ and $x_2$ must be compared.

If
- $x_1$ = striker pin energy with standard deviation $S_1$ out of $n_1$ observations,
- $x_2$ = sensitivity energy ("go-level") with standard deviation $S_2$ out of $n_2$ observations

and

$y = x_1 - x_2$ for individual results,

$Y = X_1 - X_2$ for mean values,

$$S^2_y = \{(n_1-1)*S^2_1 + (n_2-1)*S^2_2\} : (n_1+n_2-2)$$

for $k = n_1 + n_2 - 2$ degrees of freedom.

then the minimum mean overvalue $Y_{min}$ is given by:

$$Y_{min} = Y - t_{(1-\alpha),k} * \sqrt{\{(n_1+n_2):(n_1+n_2)\}} : S_y$$

and the maximum standard deviation $\sigma_{max}$ is given by:

$$\sigma^2_{max} = k * S_y^2 : chi^2_{\alpha,k}$$

The requirement y > 0 will be fulfilled with confidence 1 - α

if $$Y_{min} > t_{1-\alpha} * \sigma_{max}$$

The estimated failure rate is the probability that y > 0.

5. Models and Elaboration of On-Shot Tests

Methods for the application of go-no go tests and for the evaluation of the results are: Bruceton, UDTR, Langlie, OSTR, Probit, Robbins-Monro, Neyer and the classical run-down test. Annex B Appendix 3 of AOP-21 [b9] presents an example for estimation of the mean μ and the standard deviation σ by elaboration of a Bruceton test. Some of these tests are only applicable for a Gaussian or a log-normal distribution, others are applicable for any distribution. See further current statistical handbooks.

If the distribution law of the sensitivity of a receptor element is known, a simple verification of two levels, e.g. at 30% and 70% may be more efficient. To determine the all-function (all-fire) or no-function (no-fire threshold) levels, the one-side confidence intervals are calculated.

6. Estimation of no-fire threshold and all-fire level

6.1 No-fire threshold

For any element of an explosive or functional train within a demolition system, requirements for safety and reliability shall cover the risks of unplanned initiation due to stimuli not intended to cause initiation, but induced by the external environment or by the system environment. Such initiation could cause premature function of the munition (safety aspect) or dudding (reliability aspect). Therefore, this stimulus shall not exceed the no-fire threshold (or no-function threshold).

The no-fire threshold is the stimulus which corresponds with the maximum acceptable failure rate (probability of an unwanted reaction of the receptor). It shall be sufficiently far above the expected stimuli, e.g., at a probability of 0,001% or 0,01% estimated at the specified degree of confidence (e.g., 95%, 1-side). The exploitation of the test results to calculate this value is given in §3 and §4 above or with the respective test methods (§5).

6.2 All-fire level

For any element of an explosive or functional train within a demolition system, requirements for safety and reliability shall cover the risks of failure to initiate correctly (misfire) upon receipt of the stimuli intended to cause initiation. Such failure could cause no function of a safety feature (safety aspect) or no function of the munition (reliability aspect). Therefore, this stimulus shall not be inferior to the all-fire level (or all-function level).

The all-fire level is the stimulus which corresponds with the maximum acceptable failure rate (probability of failing to produce the specified reaction of the receptor). It shall be sufficiently far below the specified stimulus, e.g., at a probability of 0,01% or 0,1% estimated at the specified degree of confidence (e.g., 95%, 1-side). The exploitation of the test results to calculate this value is given in §3 and §4 above or with the respective test methods (§5).

6.3 Nature of the stimulus

The stimulus may be expressed as electrical, mechanical energy, or power, e.g., current-time, drop mass-height or gap width as an explosiveness parameter.